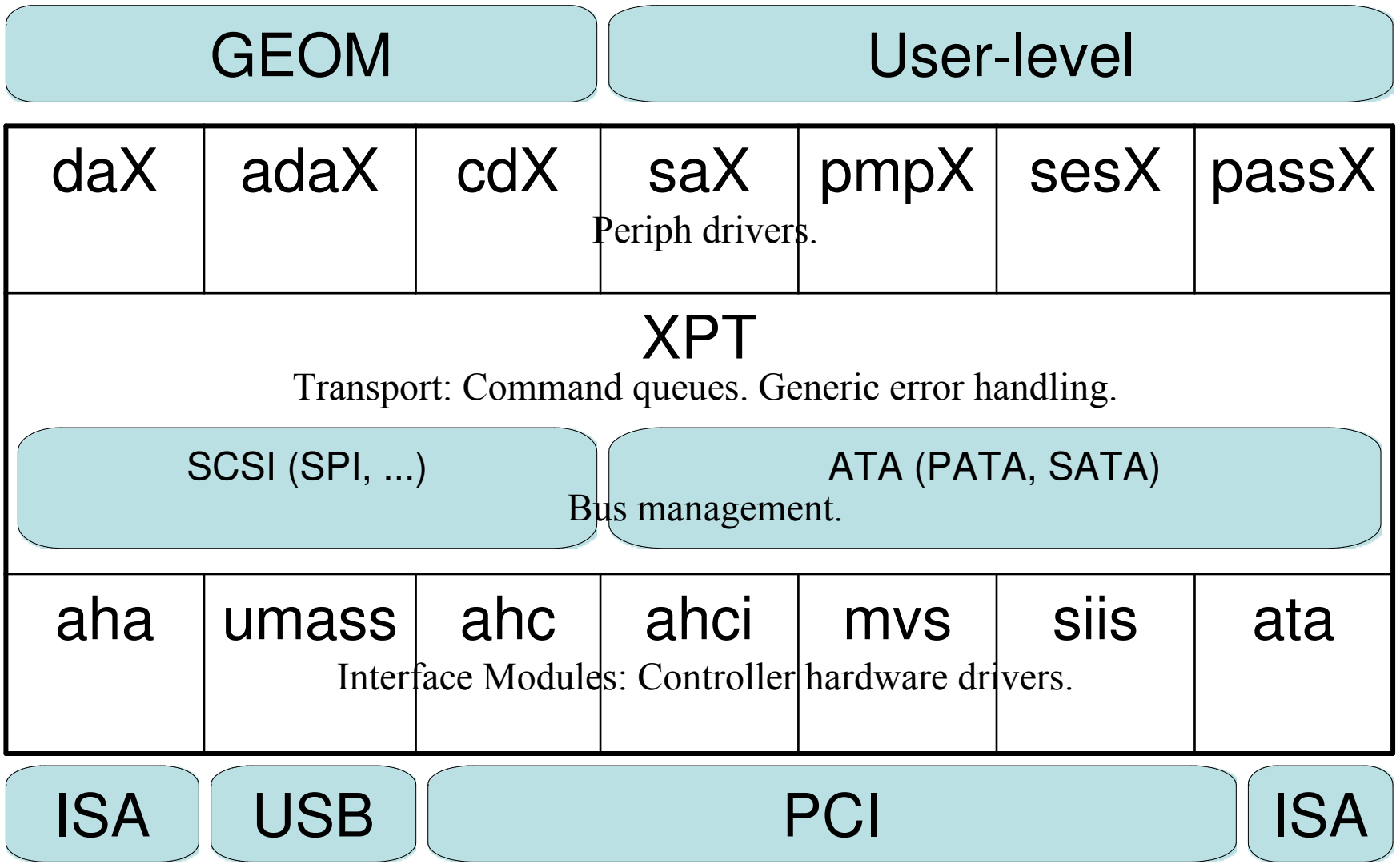
CAM-based ATA implementation
3 ... 2 ... 1 ... Lift-off!

Alexander Motin
mav@FreeBSD.org

- ATA(4) was started more then 10 years ago and handled generic ATA controllers well. But now there are problems:
  - modern controllers use different APIs - driver API was fuzzy and modern controllers still don't fit it well;
  - modern controllers support command queues - no support;
  - SATA controllers and disks support NCQ - no support;
  - SATA 2.x controllers support Port Multipliers - very limited support;
  - some with FIS-based switching - no support;
  - SATA has number of additional features, such as interface power management - no support;
  - ATAPI tunnels SCSI commands over ATA - ata(4) ATAPI drivers produce code duplication, atapicam(4) is not perfect;
  - implements unfair scheduling;
  - error recovery is quite limited due to limited state machine.

- CAM doesn't have some of problems (command queueing, fair scheduling, state machine). For others it allows solutions.
- CAM(4) improvements:
  - XPT level was split and partially virtualized to allow support for different transport types; SPI specific code moved to SCSI XPT (thanks to Scott Long);.
  - new ATA XPT implements specific management for PATA and SATA buses, including port multipliers support;
  - new XPT_ATA_IO request type allows transporting ATA protocol commands; ATAPI devices can handle both XPT_ATA_IO and XPT_SCSI_IO requests;
  - peripheral drivers do not depend on device transport (SPI, SAS, SATA, ...), only command protocol (SCSI, ATA, ...); for ATA protocol disks implemented new driver ada(4);
  - XPT code was improved to allow support more complicated bus topologies;

- Updated CAM(4) structure



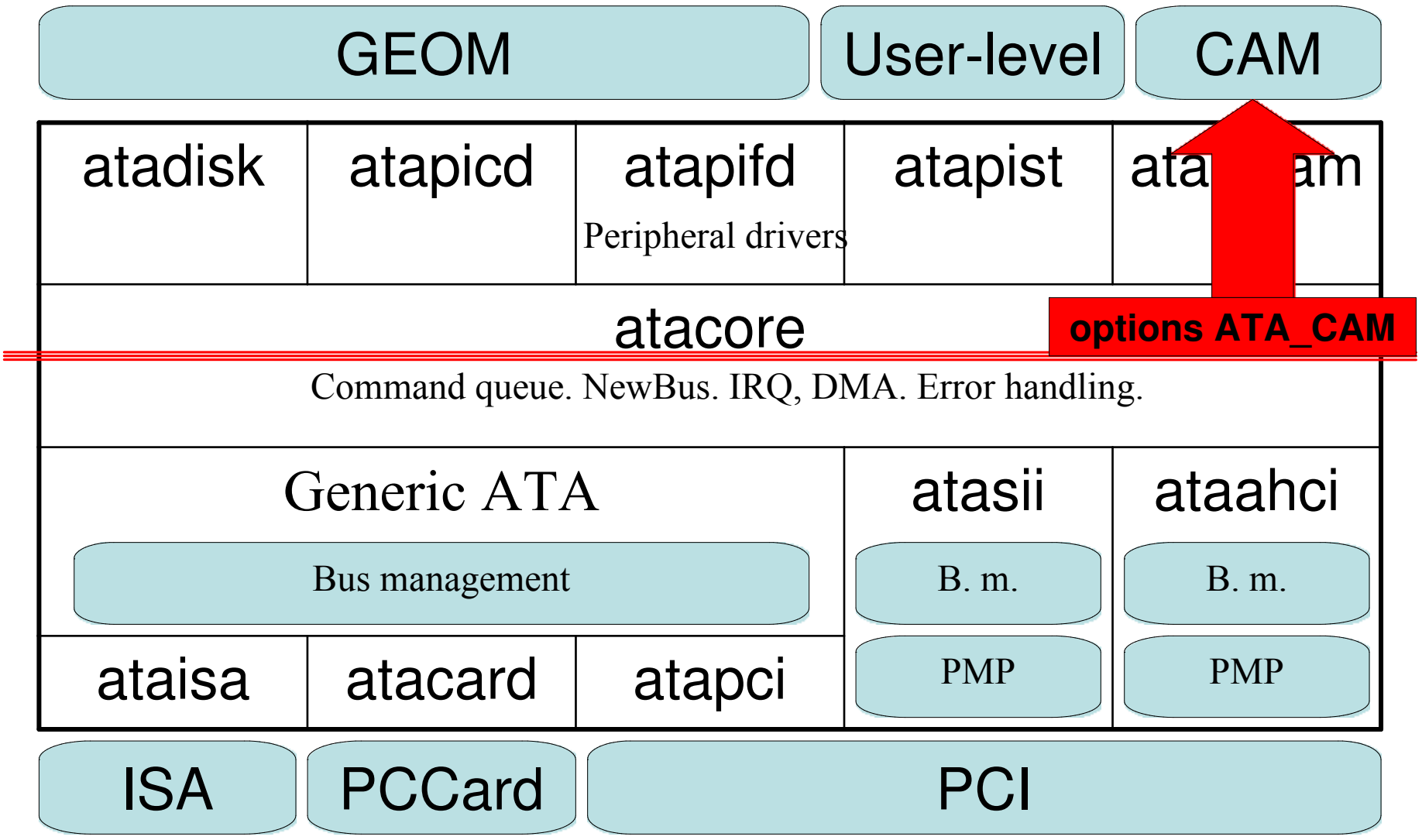
- ahci(4) driver supports:
  - integrated and add-in AHCI-compatible SATA controllers;
  - ATA and ATAPI devices;
  - each port completely independent
  - up to 32 queued commands per port;
  - NCQ;
  - SATA Port Multipliers (with FIS-based switching, when h/w supports);
  - MSI (one or multiple vectors);
  - Command Completion Coalescing (if somebody wish);
  - SATA power management;
  - I/Os of any size, up to MAXPHYS.

- mvs(4) driver supports:
  - several Marvell SATA chips: 88SX50xx, 88SX60xx and 88SX70xx, SoC;
  - ATA and ATAPI devices (ATAPI with some limitations);
  - each port completely independent;
  - NCQ (up to 31 commands per port);
  - SATA Port Multipliers (with FIS-based switching for NCQ commands, when h/w supports);
  - MSI;
  - Command Completion Coalescing (if somebody wish);
  - SATA power management;
  - I/Os of any size, up to MAXPHYS.

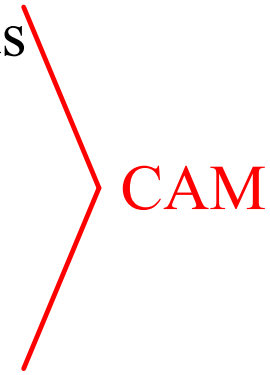
- siis(4) driver supports:
  - several SiliconImage SATA chips: SiI3124 - 4-port PCI-X, SiI3132/3531 - 2/1-port PCIe x1;
  - ATA and ATAPI devices;
  - each port completely independent;
  - 31 queued commands per port;
  - NCQ;
  - SATA Port Multipliers (with FIS-based switching);
  - MSI (works only on SiI3124);
  - device-initiated SATA power management;
  - I/Os of any size, up to MAXPHYS;

- Refactored and turned into CAM SIM by `options ATA_CAM`
  ata(4) supports:
  - all legacy ATA chips;
  - ATA and for most chips ATAPI devices;
  - no queued commands;
  - no NCQ;
  - no SATA Port Multipliers (require a lot of cleanup, difficult to keep compatibility with legacy mode);
  - MSI supported for some controllers;
  - I/Os of up to 512K size, depending on controller, respecting MAXPHYS.

- ATA(4) structure



- Kernel options:
  - 8-STABLE and 9-CURRENT support both old and new ATA stacks; 8-STABLE uses old stack by default, 9-CURRENT was recently switched to the new one.
  - To use new ATA stack kernel config should include:
    - device scbus
    - device da
    - device cd
    - device ...
    - device pass
    - device ahci
    - device ata
    - options ATA_CAM
    - device mvs
    - device siis

  - devices atadisk, atapicd, atapifd, atapist, atapicam, ataraid are not used by the new stack and should be removed.

- Kernel modules:
  - devices scbus, da, cd, pass, etc are parts of the cam module.
  - devices ahci, siis and mvs have own modules.
  - device ata same as before consists of number of ata... modules (ata, atapci, ataintel, ...).
  - `options ATA_CAM` should be present in kernel config and can’t be switched/loaded dynamically.

- Command equivalents:
  - atacontrol list — camcontrol devlist
  - atacontrol cap — camcontrol identify
  - atacontrol reinit — camcontrol reset
  - atacontrol mode — camcontrol negotiate
  - atacontrol spindown — camcontrol idle/standby/sleep
  - atacontrol create/delete/... — graid label/delete/...

- Device names equivalents:
  - adX — adaY
  - acdX — cdY
  - afdX — daY
  - astX — saY
  - To simplify migration, adX => adaY symbolic links created in /dev/, allowing to mount FSes by their old names without demanding to update /etc/fstab beforehand.
  - Mapping between names also reported during system boot.

- How it looks now (camcontrol devlist):

```
%atacontrol list
atacontrol: control device not found: No such file or directory
%camcontrol devlist
<Slimtype DVD A  DS8A1P CA11>          at scbus0 target 0 lun 0 (pass0,cd0)
<ST3250620NS 3.AEK>                    at scbus1 target 0 lun 0 (pass0,ada0)
<Optiarc DVD RW AD-7200S 1.0A>         at scbus1 target 1 lun 0 (cd1,pass1)
<Hitachi HTS542525K9SA00 BBFOC31P>  at scbus1 target 2 lun 0 (ada3,pass5)
<Port Multiplier 37261095 1706>        at scbus1 target 15 lun 0 (pass2)
<OCZ-VERTEX 1.30>                      at scbus2 target 0 lun 0 (pass3,ada1)
<ST3250620NS 3.AEK>                    at scbus3 target 0 lun 0 (pass4,ada2)
```

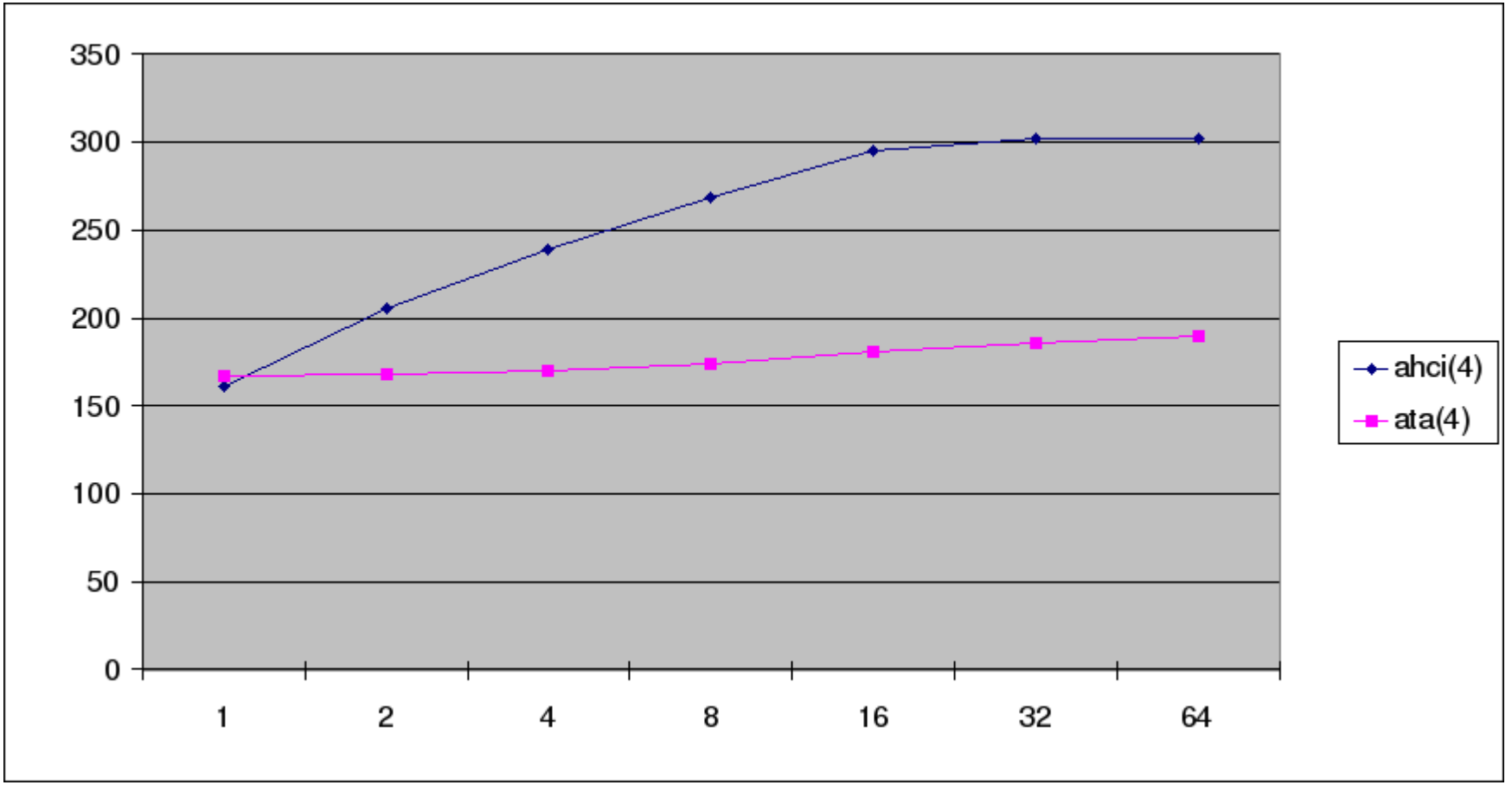
- How it looks now (dmesg):

```
ada0 at ahcich0 bus 0 scbus1 target 0 lun 0
ada0: <OCZ-VERTEX 1.4> ATA-8 SATA 2.x device
ada0: Serial Number H262LML036XYSDZVG1JI
ada0: 300.000MB/s transfers (SATA 2.x, UDMA6, PIO 512bytes)
ada0: Command Queueing enabled
ada0: 61056MB (125043311 512 byte sectors: 16H 63S/T 16383C)
cd0 at ata0 bus 0 scbus0 target 0 lun 0
cd0: <Slimtype DVD A  DS8A1P CA11> Removable CD-ROM SCSI-0 device
cd0: Serial Number 711050015684
cd0: 33.300MB/s transfers (UDMA2, ATAPI 12bytes, PIO 65534bytes)
cd0: Attempt to query device size failed: NOT READY, Medium not present
```

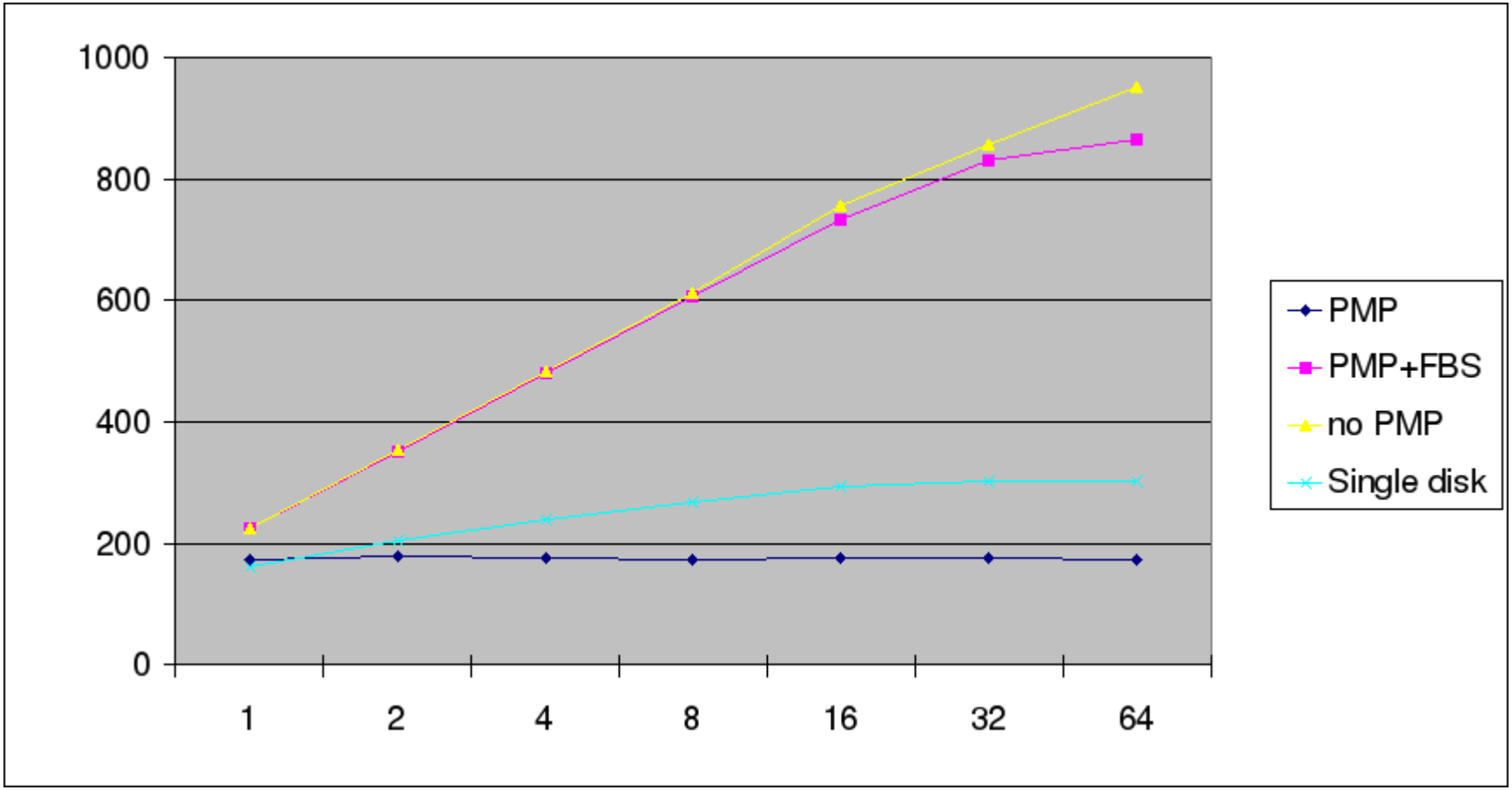
- How it looks now (camcontrol identify):

```
%camcontrol identify ada0
pass1: <OCZ-VERTEX 1.4> ATA-8 SATA 2.x device
pass1: 300.000MB/s transfers (SATA 2.x, UDMA6, PIO 512bytes)

protocol              ATA/ATAPI-8 SATA 2.x
device model          OCZ-VERTEX
firmware revision     1.4
serial number         H262LML036XYSDZVG1JI
cylinders             16383
heads                 16
sectors/track         63
sector size           logical 512, physical 512, offset 0
LBA supported         125043311 sectors
LBA48 supported       125043311 sectors
PIO supported         PIO4
DMA supported         WDMA2 UDMA6
media RPM             non-rotating

Feature                      Support  Enable    Value           Vendor
read ahead                     yes      no
write cache                    yes      no
flush cache                    yes      yes
overlap                        no
Tagged Command Queuing (TCQ)   no       no
Native Command Queuing (NCQ)   yes              32 tags
```

- Performance:
  - Number of random I/Os per second for different number of threads with legacy ata(4) driver and ahci(4). Seagate ST3320418AS on ICH10R AHCI HBA.



- Performance:
  - Number of random I/Os per second for different number of threads. gstripe of four Seagate ST3320418AS on SiI3124 HBA with SiI3726 Port Multiplier and ICH10R HBA with and without Port Multiplier.



- As soon as ataraid(4) driver is not applicable to the new ATA stack, RAID GEOM class was implemented to handle BIOS-based software RAIDs.
- RAID GEOM follows modular design with APIs based on KOBJ and consists of such parts: core, transformation modules, metadata modules and graid(8) control tool.
  - core part handles requests and events queues, geom interoperation, etc.
  - transformation modules handle different data transformations, implementing different RAID levels. Now implemented: RAID0, RAID1, RAID1E, RAID10, SINGLE, CONCAT.
  - metadata modules handle all vendor-specific things, such as metadata fornats, disks and volumes management, spare disks, etc. Now implemented: Intel, JMicron, NVIDIA, Promise (also used by AMD/ATI) and SiI.

- Special thanks to:
  - iXsystems Inc. for supporting my work;

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- Questions?